Transient Load Analysis and Testing of QuikSCAT Spacecraft

C.P. Kuo
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, Ca 91109

Michael Vujcich
Ball Aerospace & Technologies Corp.
Boulder, CO 80306

Abstract

The QuikSCAT satellite was successfully launched aboard a Titan II launch vehicle on June 19, 1999 from Vandenberg Air Force Base. The QuikSCAT mission was the first contract awarded under the NASA Rapid Spacecraft Acquisition (RSA) program and had a very aggressive development schedule (one year from contract award to launch). The compressed schedule necessitated a modified approach to the loads analysis and environmental testing program from that of a typical spacecraft program. In addition, higher loads encountered well into the design phase required a high degree of coordination and cooperation between the spacecraft contractor Ball Aerospace, the launch vehicle contractor Lockheed Martin Astronautics, NASA/JPL, NASA/GSFC, as well as technical input provided by Aerospace Corporation. This paper will detail the approach used to develop spacecraft design loads, associated risks, and lessons learned.

The spacecraft contract was awarded in November, 1997. A preliminary structural sizing was performed using load factors specified in the Titan II users guide and a mathematical model was developed for coupled loads analysis (CLA). Secondary structure load factors were generated from a mass acceleration curve developed by JPL and a base drive random response analysis performed by Ball Aerospace.

Due to schedule constraints, **only** a single CLA cycle was planned for the program instead of the multiple cycles typically performed. The spacecraft bus structural design was complete and fabrication well underway prior to receipt of the CLA results. In order to reach the required orbit the Titan II **launch vehicle had to use a Stage I burn to oxidizer deletion instead of the more benign commanded Stage I shutdown.** The CLA results **for this event** unfortunately indicated that the lateral loads on the spacecraft were significantly higher than **those** used for structural design. It was determined that the QuikSCAT

spacecraft was the lightest and stiffest payload flown to **date on Titan II** and that there was a significant coupling of the spacecraft primary bending modes with the booster modes which had not been experienced **on previous missions.**

Various approaches were explored to solve the loads issue. An isolation system at the interface between the spacecraft and the launch vehicle was proposed to reduce the coupling between the spacecraft and the launch vehicle. The isolation system was not **implemented** due to its complexity as well as schedule and resource constraints. **An alternative** statistical treatment of the loads generated a rational approach by **removing** several outliers from the **family of forcing functions** to reduce design loads but **this** was generally not embraced by the community due to it's reduced conservatism.

A study was performed to establish the sensitivity of the design loads due to variations in the spacecraft model. The results of this study showed that the design loads could increase by as much as 10 % over the predicted CLA results. The **adopted** approach was to perform a refined stress analysis in order to establish positive margins and to fly **the** current design in conjunction with **an** extensive test program. The model was correlated after the vibration test and the loads were verified by a CLA for only the most critical case, the Stage I shutdown using the oxidizer depletion.

Environmental testing at the spacecraft level consisted of quasi-static sine burst testing for strength, base drive random vibration testing for workmanship, and direct excitation acoustic testing using portable speakers. The vibration tests were performed using a force-limited methodology with a fixture incorporating force gages to measure base shear, axial force, and bending moments. A modal survey was not planned due to schedule constraints. A fairly extensive pre-test analysis was performed and a limited model correlation was performed using the vibration test data. Due to the limited amount of modal data collected, a dynamic uncertainty factor of 1.25 was retained throughout the program. Environmental testing was successful and the spacecraft was shipped to the launch site on schedule.